Toward an Improved Understanding of the Role of Transpiration in Critical Zone Dynamics

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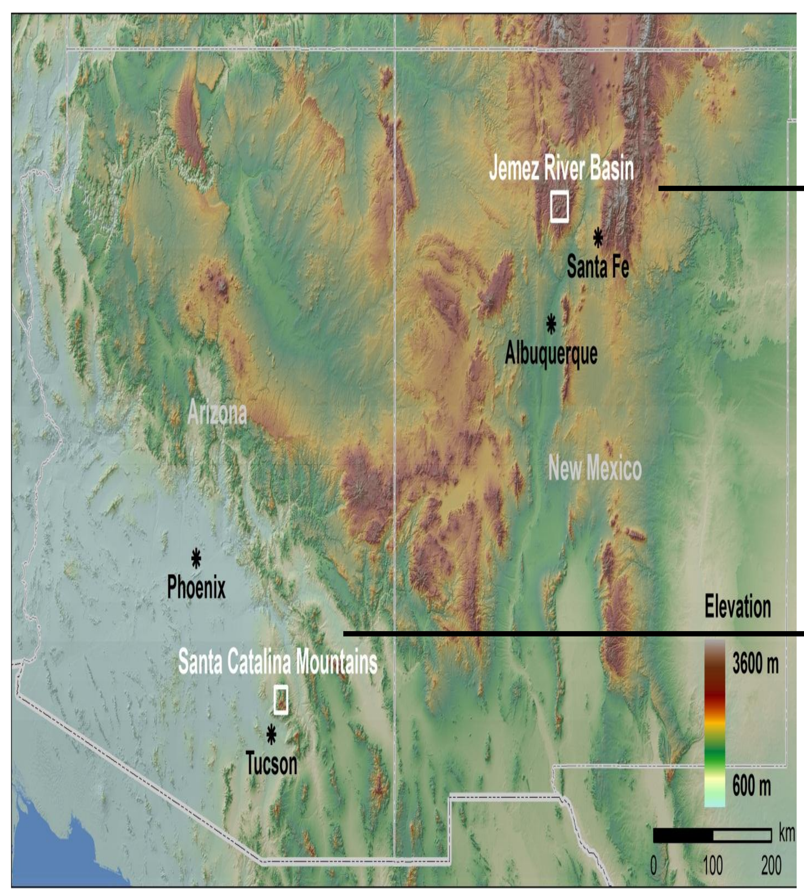
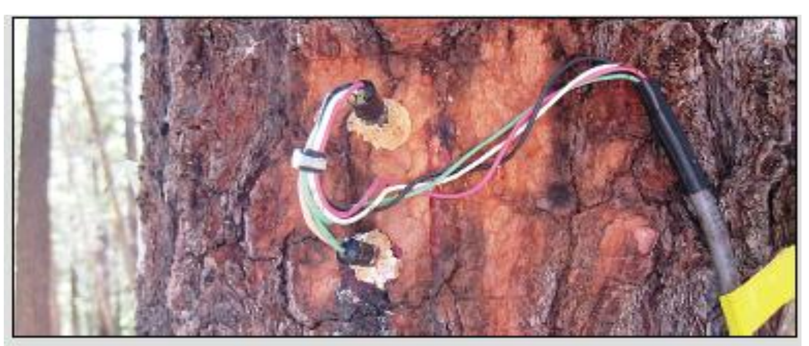
Introduction

Evapotranspiration (*ET*) has been documented to be greater than **<u>90%</u>** of total precipitation in dryland ecosystem. The biological (*T*) and non-biological component (*E*) of *ET* are regulated by different mechanisms and inability to separate the two components 'black boxes' our ability to determine how biological available water modulates the hydrologic pathway across multiple spatial and temporal scales . Objective of our study was therefore to quantify the sensitivity of transpiration of coexisting tree species in high elevation mixed conifer ecosystem to soil moisture, soil temperature and environmental factors.

Study Site

Our study sites are located within the Jemez River Basin – Santa Catalina Mountains Critical Zone Observatory (JRB – SCM CZ) The high elevation zero order basin (ZOB) at JRB CZ (32º25'45"N 110º46'0"W) is located within the Rio Grande basin at Valles Caldera National Preserve in north central New Mexico while at SCM CZ the ZOB is located within the Marshall Gulch experimental site at Coronado National Forest of southern Arizona (32º25'45"N 110º46'0"W).





Sap Sensors

Sap sensors were installed in four Spruce (*Picea abies*) and four Fir (*Abies*) trees at the JRB CZ site and at four White Fir (*Abies concolor*), four Maple (*Acer pseudoplatanus*) along an east-west transect in the SCM CZ site

Meteorological &Soil Moisture Meas.

Weather station logged air temperature (T_a) , relative humidity (*RH*) ,net radiation (R_n) measurements and precipitation data (PPT). Soil moisture /temperature (T_s) data at 15, 30 and 50 cm depth were logged at 30 – min interval. Def. of shallow, deep and avg., soil moisture and soil temp based on meas. at multiple depths have been provided.

Description	Symbol	Jemez, NM	Schist, AZ
Shallow Temp.	T_s	T_{15}	T_{10}
Deep Temp.	T_d	T_{30}	T_{30}
Avg. Temp	T_a	$(T_{15} + T_{30} + T_{50})$ /3	$(T_{10} + T_{30})$ /2
Shallow Moisture	Θ_s	Θ_{15}	Θ_{15}
Deep Moisture	Θ_d	Θ_{50}	Θ_{50}
Avg. Moisture	Θ_a	$(\Theta_{15} + \Theta_{30} + \Theta_{50})$ /3	$(\Theta_{15} + \Theta_{30} + \Theta_{50})$ /3

Vapor Pressure Deficit (VPD)

$$= a * e\left(b * \frac{T}{T+c}\right) * (1 - RH)$$

T = Air Temp, RH = Rel.Humidity
a= 0.611, b = 17.502, c = 240.97

Hypothesis

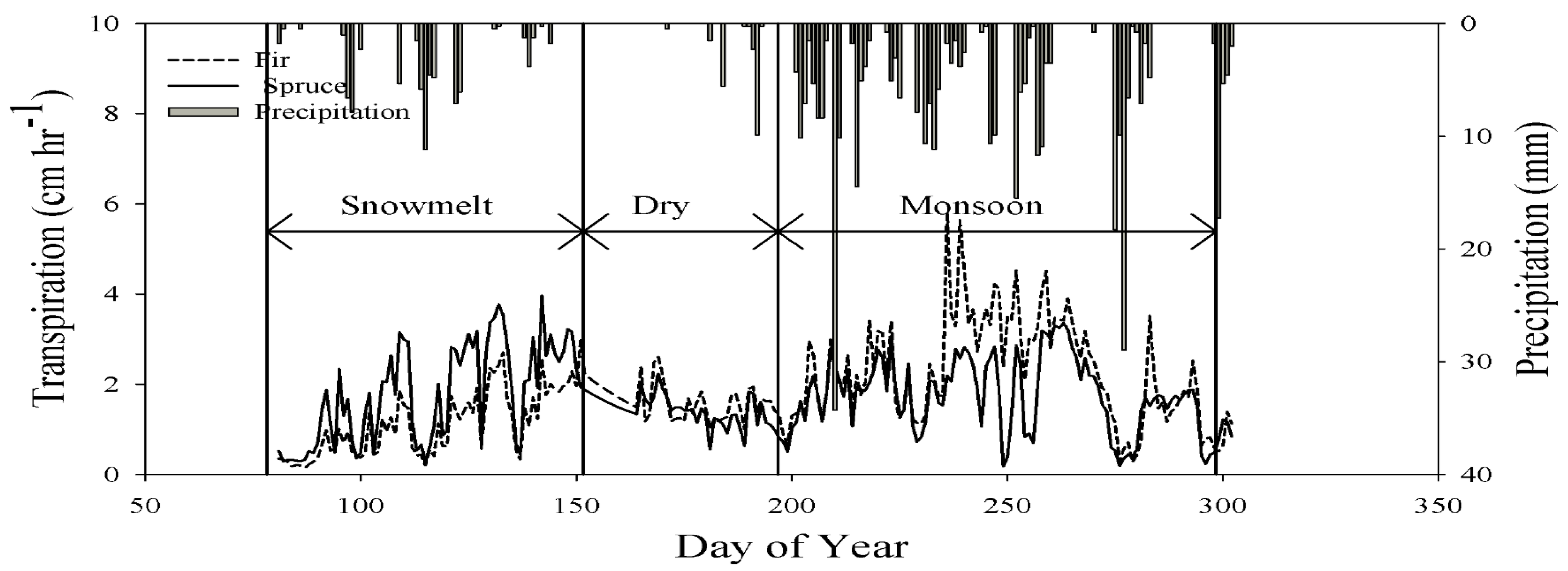
Hyp 1: Soil temperature drives transpiration during the snowmelt period in the mixed conifer ecosystem during the snowmelt period (**<u>Energy Limited System</u>**).

Hyp 2: Vapor Pressure Deficit (VPD) drives transpiration during the dry period.

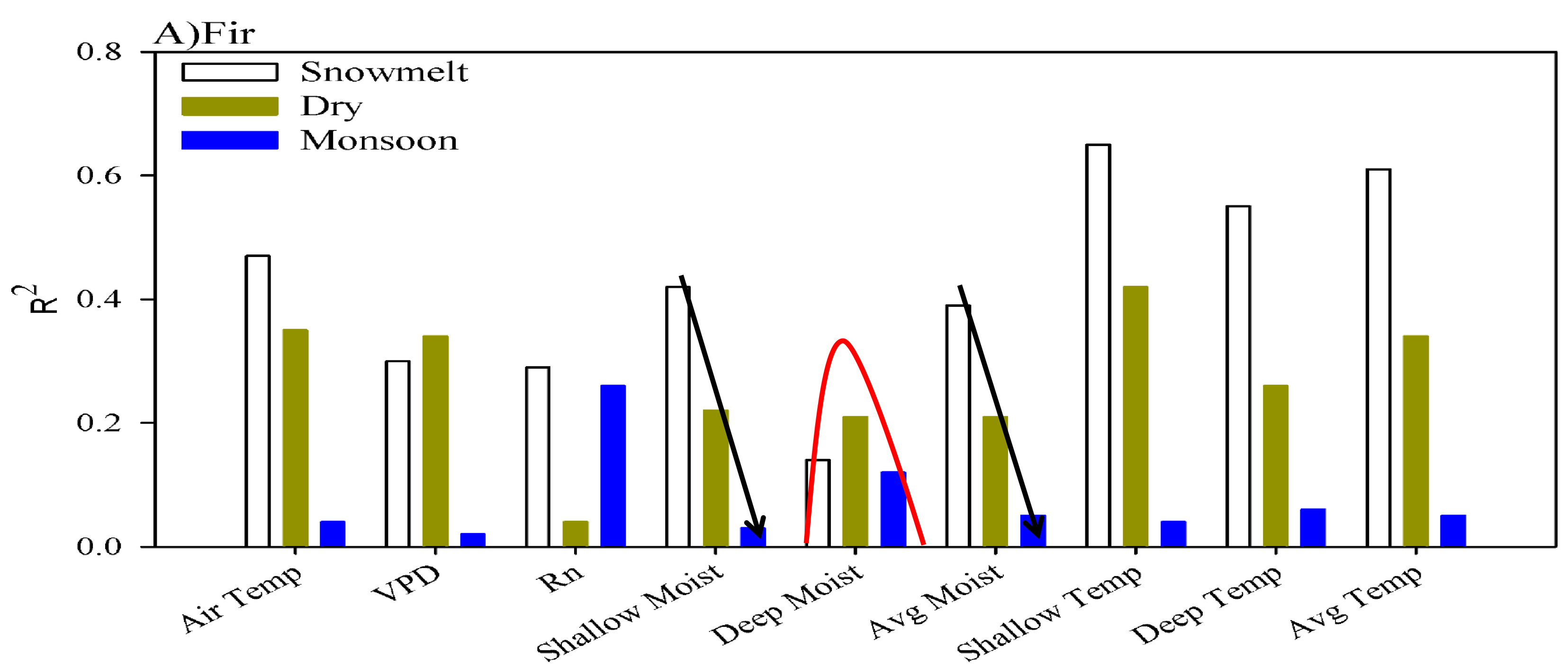
Hyp 3: Soil Moisture drives transpiration during the monsoon period (**<u>Moisture Limited System</u>**).

Hyp 4: Environmental controls of transpiration are species independent

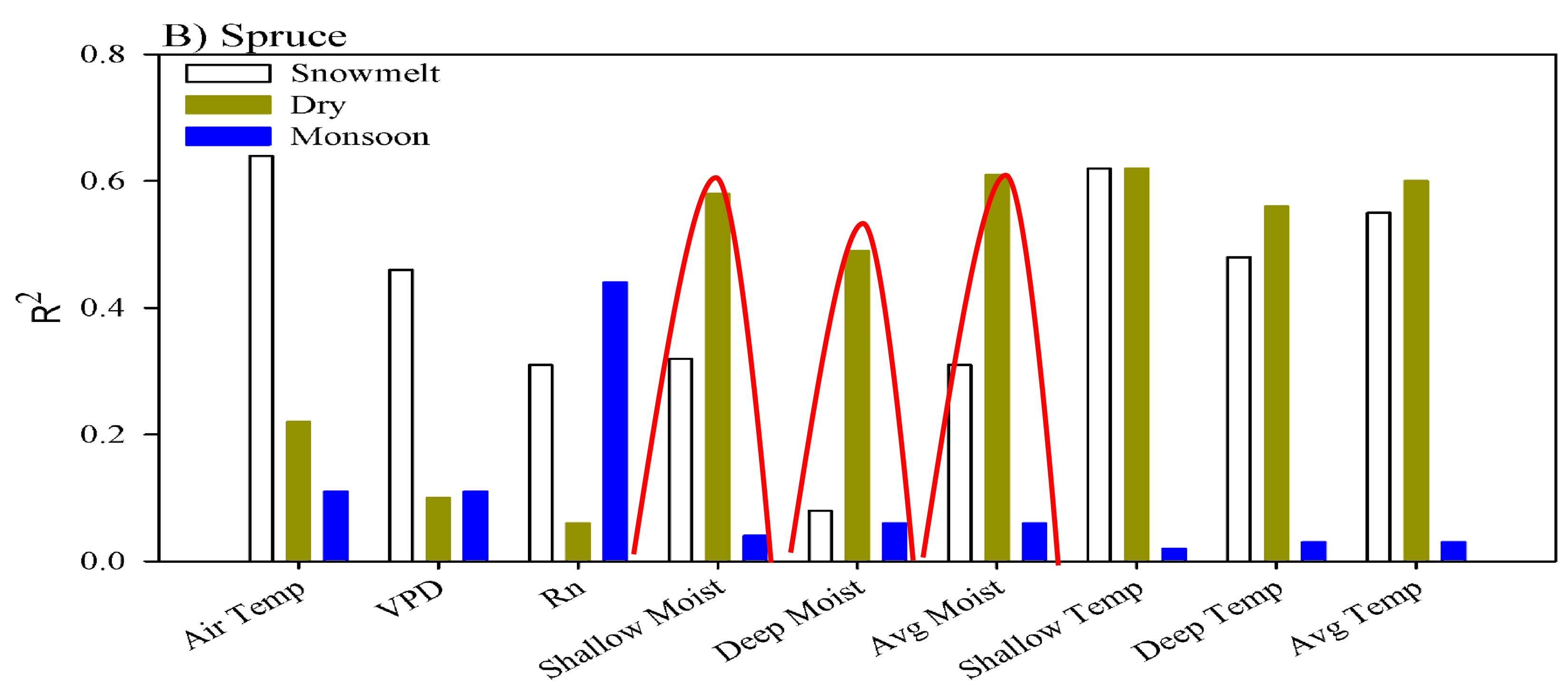
<u>Analysis of Transpiration : Jemez, NM</u>



- We used snowmelt and precipitation data to define our study period into three distinct season; 'Snowmelt' (DOY 71 – 150), 'Dry'(DOY 150 – 181) and 'Monsoon' (DOY 182 – 302).
- 83.5% of the total precipitation occurred during the monsoon period while 14..25 and 2.18% of the total precipitation occurred during the snowmelt and dry period respectively

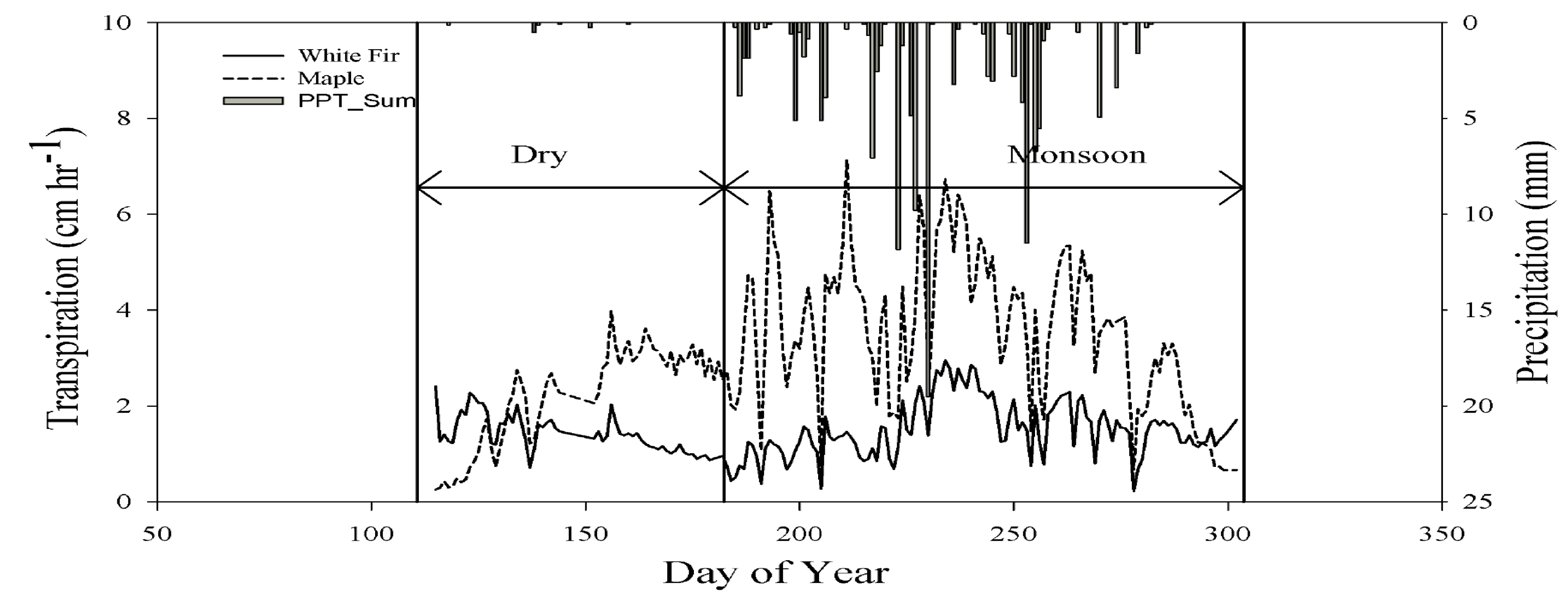


- Air temp along with soil temperature was a strong driver of transpiration of fir during the snowmelt period.
- Influence of soil moisture at shallow as well as average depth decreased monotonically from snowmelt to monsoon period.

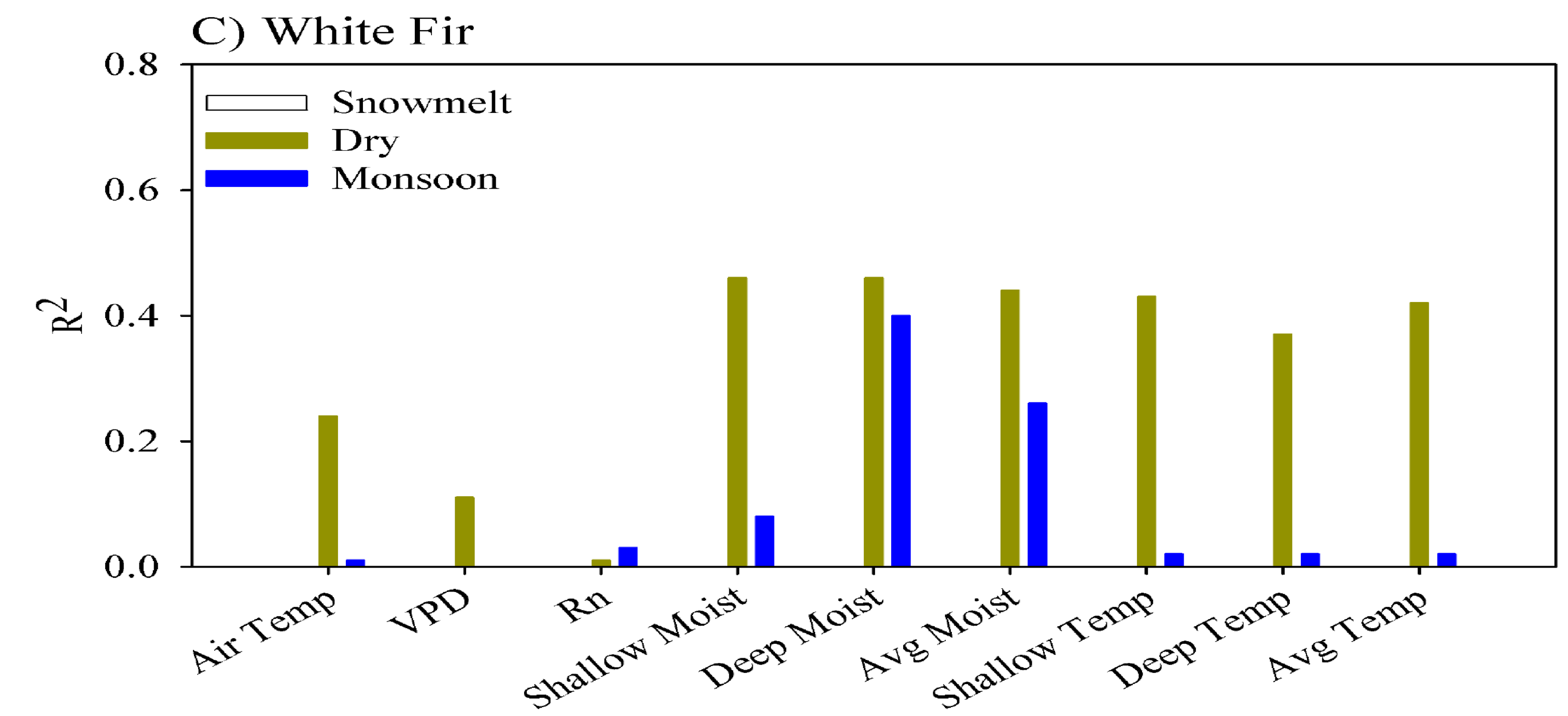


- Air temp along with soil temperature was a strong driver of transpiration of spruce during the snowmelt period.
- Soil moisture at deeper depth strongly modulated the transpiration rate of spruce

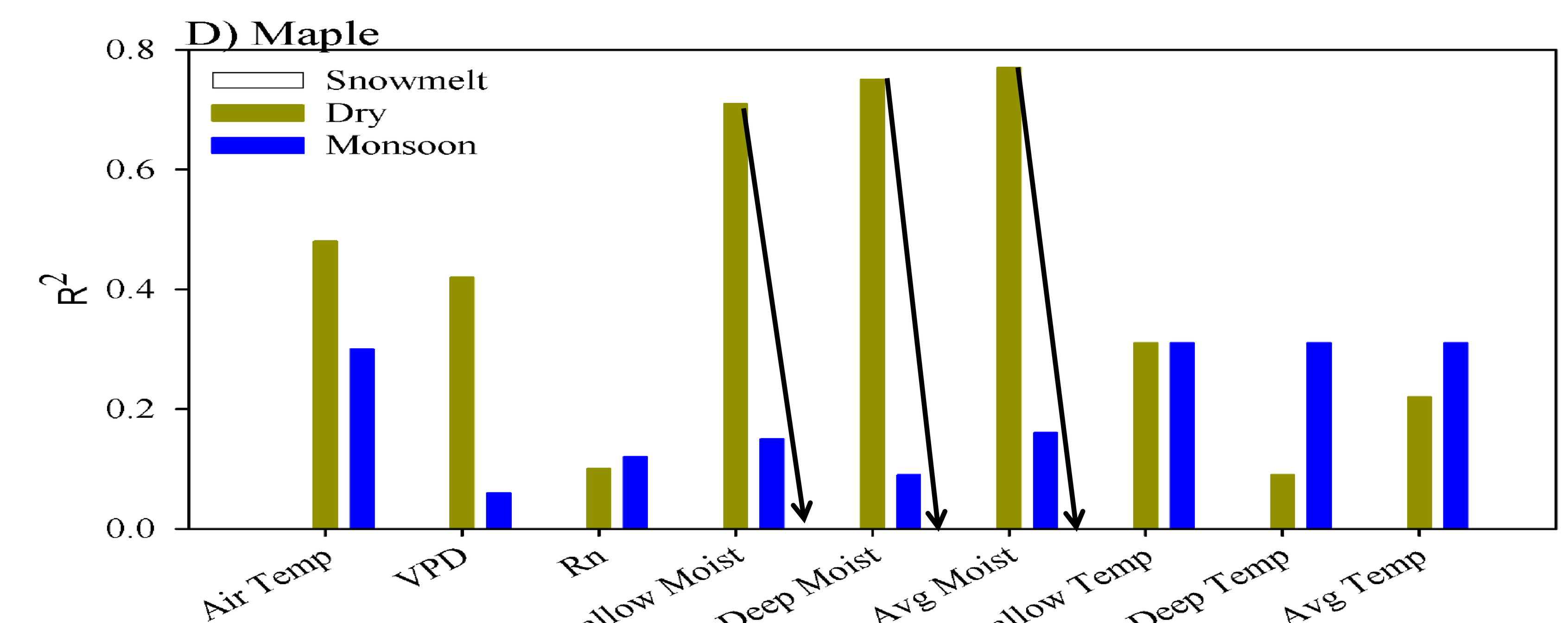
<u>Analysis of Transpiration: Marshall Gulch, AZ</u>



- We used the total precipitation data to divide the time period of our analysis into two distinct seasons: dry (0.85% ppt, DOY 115 – 181) and monsoon (98.15% ppt, DOY 182 – 305).
- Transpiration rate of deciduous maple was four times greater than evergreen white fir



- None of the meteorological factors influenced the transpiration rate of white fir
- Moisture at shallow depth influenced the transpiration rate during the dry period while strength of the correlation with moisture at deeper depth remained strong both during the dry and monsoon period.



- Strength of the correlation of transpiration rate with moisture across all depth was strongest during the dry period which drastically reduced during the monsoon period
- Air temp and VPD was a weak driver of transpiration during the dry period.

Summary

- Hyp1 :<u>Soil temp</u> was the primary driver of transpiration during snowmelt period.
- Hyp 2:<u> VPD was not</u> the primary driver of transpiration during the dry period for both Jemez and Marshall Gulch
- Hyp 3: <u>Soil moisture was not a</u> driver of transpiration during the monsoon period.
- Hyp 4: Environmental drivers are different for coexisting tree species in the subalpine ecosystem at both Jemez, NM and Marshall Gulch, AZ.

Implications

- Different Drivers of transpiration complicates estimation of catchment scale water balance.
- Moisture uptake by coexisting tree species were from different soil moisture depths
- Root distribution appears to play a significant role in modulating the difference in transpiration rate by coexisting tree species
- **<u>Unanswered question</u>** - Will improved understanding of surface water flow and ground water dynamics help to better understand transpiration rate during the monsoon period?

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